UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

BACKWATER INVESTIGATIONS OF THE COLUMBIA RIVER RESERVOIR

Hydraulic Laboratory Report No. Hyd-321

RESEARCH AND GEOLOGY BRANCH

DESIGN AND CONSTRUCTION DIVISION
DENVER, COLORADO

October 5, 1951

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Laboratory Report No. Hyd-321
Hydraulic Laboratory
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Reviewed by: D. M. Lancaster
C. W. Thomas

Subject: Backwater investigations of the Columbia River Reservoir

PURPOSE

The construction of Grand Coulee Dam created the problem of excessive backwater up the river channel through the International Boundary. Channel improvements in the area of the Little Dalles were made in order to reduce the backwater conditions caused by the construction of the dam.

The purpose of this study is to compare the actual backwater conditions on the Columbia River at the International Boundary and through the Little Dalles due to the presence of Grand Coulee Dam and channel improvements with the backwater conditions predicted from computations made prior to the above construction with the assistance of observations on a hydraulic model. A comparison is also made of the backwater conditions prior to and after the construction of Grand Coulee Dam and channel improvements.

CONCLUSIONS

A very close correlation was obtained between the field observations and the model-computation predictions for the backwater conditions through the Little Dalles and at the International Boundary on the Columbia River.

INTRODUCTION

The construction of Grand Coulee Dam on the Columbia River raised the problem of excessive backwater at the International Boundary and between the International Boundary and the upper end of a restricted section of River Channel known as the Little Dalles. The original investigations were made to determine these backwater conditions in advance and to develop a plan of channel improvement to relieve excessive amounts

of backwater. Computations, made with the assistance of observations on the Little Dalles hydraulic model, indicated that channel improvements in the restricted section of the river should be made. Excavation to an elevation of 1255 was performed in the Little Dalles in accordance with Excavation Plan 5, Hydraulic Laboratory Report No. Hyd-89 dated December 10, 1940. The Location Map, Figure 1, shows the locations of Grand Coulee Dam, the Little Dalles with Observation Stations 11 and 13, and Observation Station 2 at the International Boundary. Figure 2 is a topographic map showing the original details of the Little Dalles, while Figure 3 shows Excavation Plan 5 for the Little Dalles.

Because of the uncertainty of the predictions which were necessarily based on meager information, advantage was taken of the opportunity to utilize field measurements obtained after construction to verify the model studies and the computations.

A discussion by D. C. McConaughy of the paper "Conformity between Model and Prototype: A Symposium" (Transactions of the A.S.C.E., No. 109, 1944, pp 148-150) presented the then available data on the model-prototype comparison for this Grand Coulee backwater study. Comparisons in that discussion utilized data for discharges between 94,700 and 276,000 second feet, while this present report utilizes data for discharges between 200,000 and 550,000 second feet.

COMPUTATIONS AND LABORATORY STUDIES

Computations and laboratory studies were made during the year 1940. Three Hydraulic Laboratory reports, written by W. M. Borland and R. A. Goodpasture and entitled "Backwater Investigations of the Columbia River Reservoir," described the work in detail. The preliminary report, Hyd-82, is dated May 27, 1940. The intermediate report, Hyd-87, is dated November 28, 1940, while the third and final report, Hyd-89, is dated December 10, 1940. This final report is complete in itself and covers the entire investigation in detail.

During the investigation of the hydraulic properties of the Columbia River between Grand Coulee and the International Boundary, it was found that the roughness coefficient, "n," in the Kutter-Chezy formula varied with both the discharge and the river stage. Therefore, backwater computations were made using both "natural" and "backwater" roughness coefficients. The "natural" coefficients were based on the assumption that the value of "n" varied only with the discharge, while the "backwater" coefficients were assumed to vary only with stage. At the higher flows and stages the "natural" and the "backwater" coefficients were identical. Computed results using both types of roughness coefficients are compared, in this report, with the field observations.

AVAILABLE FIELD DATA

Pertinent field data available for use in making the comparisons with the computed results consisted of (1) Columbia River discharge measurements at the International Boundary, (2) Columbia River gage elevations for various stations between the reservoir and the International Boundary, and (3) the reservoir elevations at Grand Coulee Dam. These data are for the flood years of 1943, 1946, and 1948. Inasmuch as all computations were made assuming the reservoir to be at elevation 1290.00, the field observations used were restricted to data obtained with the reservoir elevation at 1290 plus or minus 0.25 foot. It is assumed that flows are the same at all three stations involved in this report. Any inflow that did occur between the International Boundary and the lower end of the Little Dalles was considered negligible. This assumption is discussed in detail in the three prior reports.

The discharge and stage data at the International Boundary were obtained from a Geological Survey gaging station, while the water stage data at the Little Dalles were obtained from Bureau of Reclamation stations.

COMPARISON OF PREDICTED AND ACTUAL BACKWATER CONDITIONS

Station 2--International Boundary. At the International Boundary (Station 2) there was a very close correlation between the computed backwater and the observed backwater elevations as shown in Figure 4. For discharges under 360,000 second feet the field observations follow very closely the computed values based on the "backwater" roughness coefficients. Above this discharge "backwater" and "natural" roughness coefficients give identical results. Maximum deviation between computed and observed values is one-half foot.

Station 11--Upper end of the Little Dalles. The backwater elevations at Station 11 near the upper extremity of the Little Dalles follow a similar pattern to that of Station 2 at the International Boundary. The maximum deviation of the observed values from the computed ones is one-half foot.

Station 13--Lower end of the Little Dalles. The correlation between predictions and observations at Station 13 at the lower end of the Little Dalles is not as close as that at Stations 2 and 11. The observed values average approximately 1 foot lower than the predicted values, Figure 4.

COMPARISON OF BACKWATER CONDITIONS BEFORE AND AFTER DEVELOPMENT

Station 2--International Boundary. Figure 5 compares field observations of backwater conditions prior to the Grand Coulee development, which includes excavation at the Little Dalles, with similar observations made after the completion of the development. Up to a discharge of 350,000 second feet the water-surface elevations at the International Boundary were from 0 to 1 foot higher after the completion of the development. However, at higher discharges the water-surface elevations were appreciably lower after the completion of the development. At a discharge of 550,000 second feet the river stage was lowered 1.4 feet by the channel improvements.

Station 11--Upper end of the Little Dalles. The effect of the 1290 reservoir elevation is very noticeable in the before and after development backwater comparisons at Station 11, Figure 5. Up to a discharge of 390,000 second feet the reservoir elevation is the controlling factor and the water-surface elevations are higher after the completion of the development. At higher discharges the Little Dalles excavation controls and the water surface becomes lower after the completion of the development. At a discharge of 550,000 second feet the water surface is lower by 6 feet.

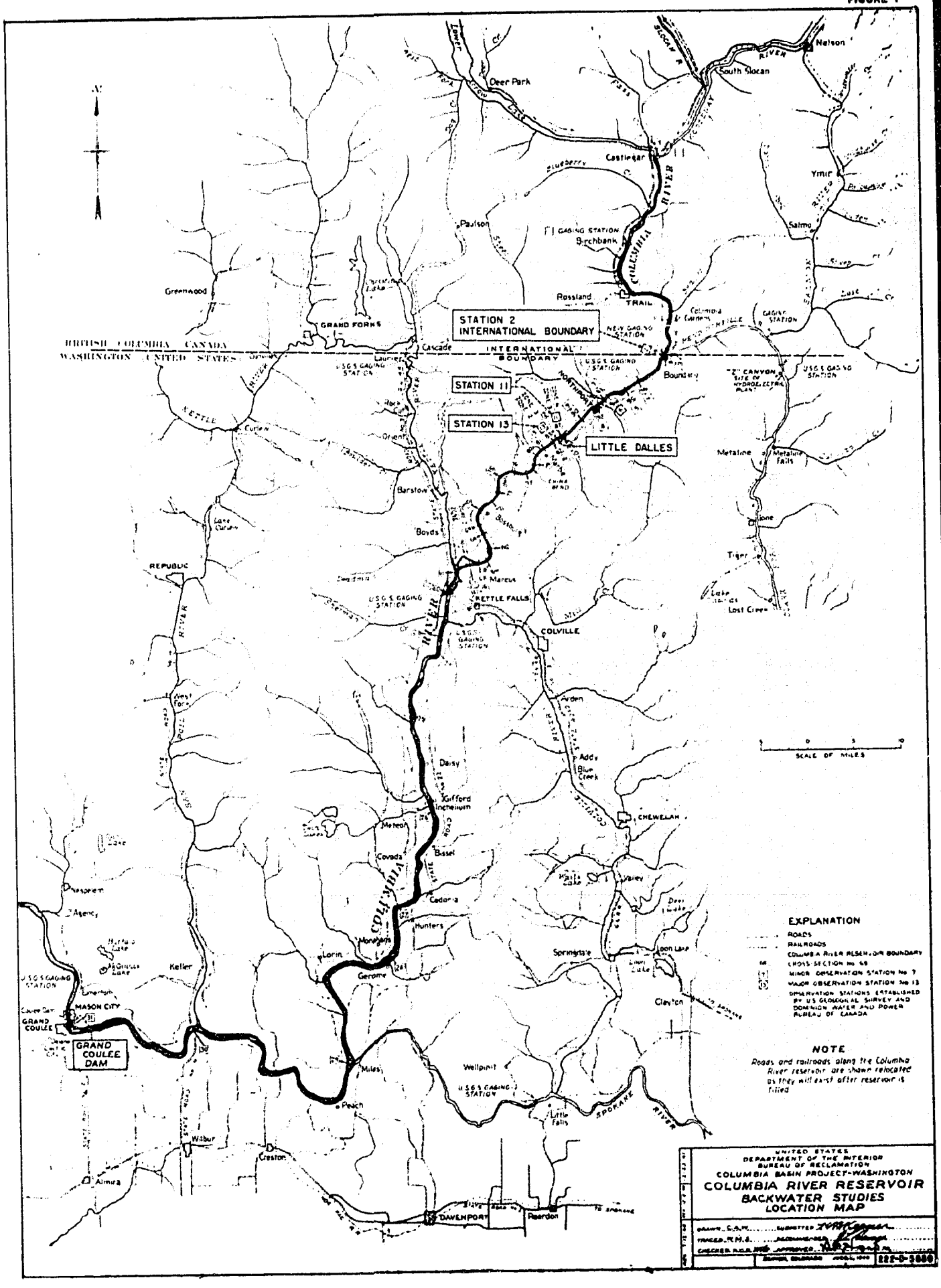
Station 13--Lower end of the Little Dalles. Figure 5 shows that for all discharges the water-surface elevations were higher after the completion of the Grand Coulee development. This is due to the 1290 elevation of the reservoir.

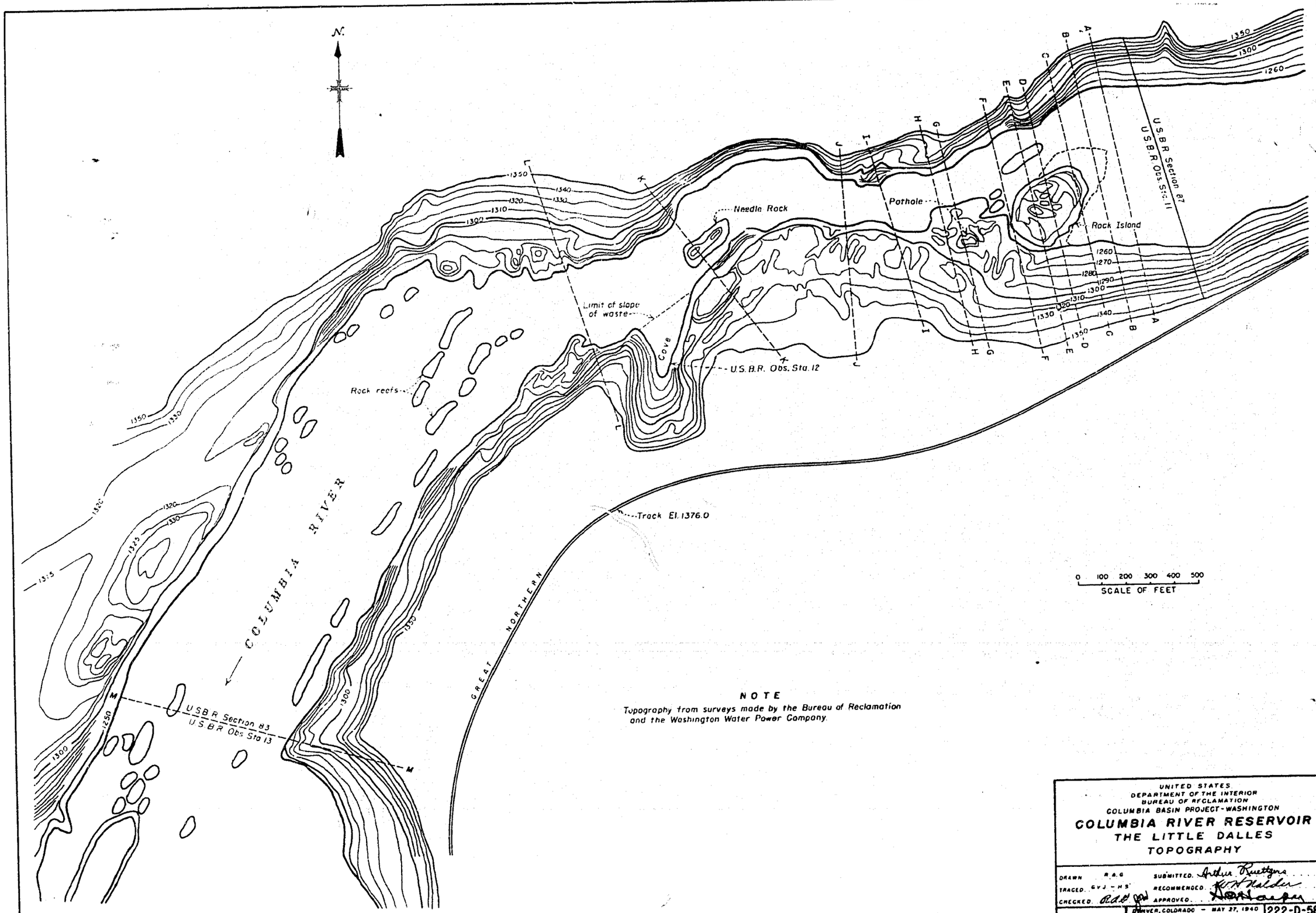
PHOTOGRAPHIC COMPARISONS OF THE LITTLE DALLES BEFORE AND AFTER EXCAVATION

Figures 6 to 14, inclusive, are photographs taken before and after the excavation at the Little Dalles. Four photographs show the conditions prior to excavation, while three photographs show the conditions after the excavation work was completed. The two remaining photographs are of the 1 to 120 scale model and show the excavated conditions. The photographs, together with the titles, are self-explanatory.

Interior - Reclamation - Denver, Colo.

FIGURE 1


N
Nelson
South Slocan
Slocan River
Deer Park
Castlegar
Columbia River
Ymir
Salmo
Paulson
Blueberry Creek
Gaging Station
Birchbank
Greenwood
Rossland
TRAIL
Columbia Gardens
Kettle River
Gaging Station
GRAND FORKS
STATION 2
INTERNATIONAL BOUNDARY
New Gaging Station
BRITISH COLUMBIA CANADA
WASHINGTON UNITED STATES
Cascade
INTERNATIONAL BOUNDARY
Laurier
U.S.G.S. Gaging Station
Boundary
U.S.G.S. Gaging Station
Z Canyon Site of Hydroelectric Plant
U.S.G.S. Gaging Station
STATION 11
STATION 13
LITTLE DALLES
Curlew
Orient
Barstow
Metaline
Metaline Falls
Lone
Boyds
Lake Curlew
Tiger
REPUBLIC
Le Marcus
KETTLE FALLS
U.S.G.S. Gaging Station
Lost Creek
COLVILLE
U.S.G.S. Gaging Station
Arden
Addy
Blue Creek
Daisy
Clifford
Inchelium
Meteor
Coyote
Bissel
CHEWELAH
Cedonia
Valley
Hunters
Honeyford
Springdale
Loon Lake
Lorin
Jerome
Keller
U.S.G.S. Gaging Station
Omerton
Coulee City
MASON CITY
GRAND COULEE
GRAND COULEE DAM
Clayton
To Spokane
Wellpinit
U.S.G.S. Gaging Station
Miles
Peach
Little Falls
Spokane River
Wilbur
Creston
Almira
DAVENPORT
Reardon
To Spokane
0 5 10
SCALE OF MILES
EXPLANATION
Roads
Railroads
Columbia River Reservoir Boundary
Cross-section No 68
Minor observation station No 7
Major observation station No 13
Observation stations established by U.S. Geological Survey and Dominion Water and Power Bureau of Canada
NOTE
Roads and railroads along the Columbia River reservoir are shown relocated as they will exist after reservoir is filled
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
COLUMBIA BASIN PROJECT-WASHINGTON
COLUMBIA RIVER RESERVOIR
BACKWATER STUDIES
LOCATION MAP
DRAWN C.S.M. SUBMITTED
TRACED R.M.A. RECOMMENDED
CHECKED APPROVED
BOISE, IDAHO JUNE, 1948
222-D-5000



NOTE

Topography from surveys made by the Bureau of Reclamation and the Washington Water Power Company.

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COLUMBIA BASIN PROJECT - WASHINGTON

COLUMBIA RIVER RESERVOIR
THE LITTLE DALLES
TOPOGRAPHY

DRAWN	R.A.G.	SUBMITTED	Arthur Ruettgers
TRACED	G.V.J. - H.S.	RECOMMENDED	K.K. Holden
CHECKED	R.A.G.	APPROVED	Harlan Bashore

DENVER, COLORADO — MAY 27, 1940 | 222-D-5885

FIGURE 3

PLAN

SECTION "D"

SECTION "F"

SECTION "J"

SECTION "K"

DETAIL "M"

NOTE

For location of additional area for waste material see Dwg. 222-D-6669

Dumped fill

Excavation

UNITED STATES
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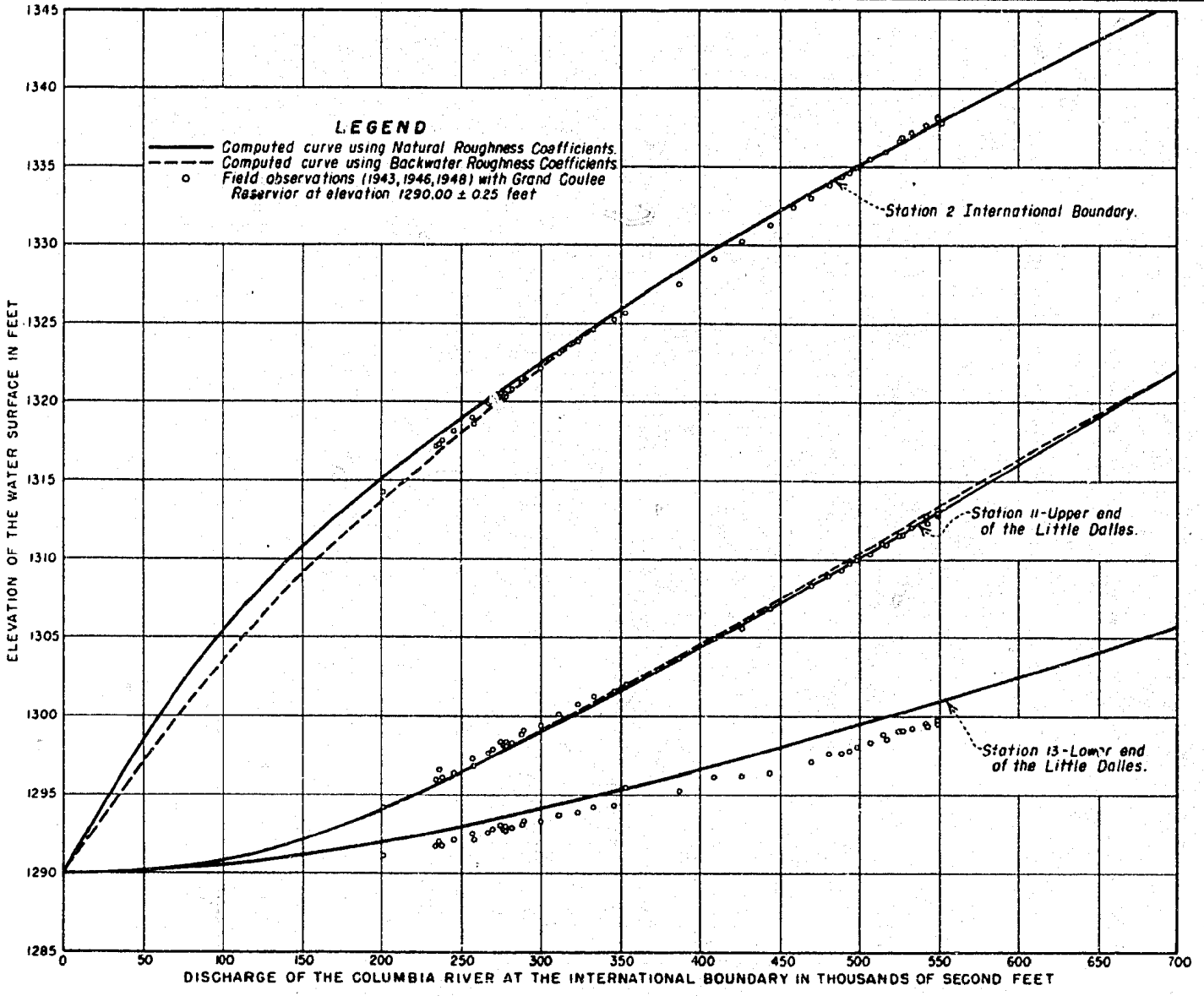
COLUMBIA BASIN PROJECT-WASHINGTON

CHANNEL ENLARGEMENT AT LITTLE DALLES
EXCAVATION PLAN AND SECTIONS

DRAWN E.M.H. SUBMITTED
TRACED W.M.S. RECOMMENDED
CHECKED APPROVED

DENVER, COLORADO OCT. 12, 1940

222-D-6670



COLUMBIA RIVER BACKWATER STUDIES

WATER SURFACE ELEVATIONS

COMPARISON-COMPUTED VS OBSERVED VALUES

FIGURE 4

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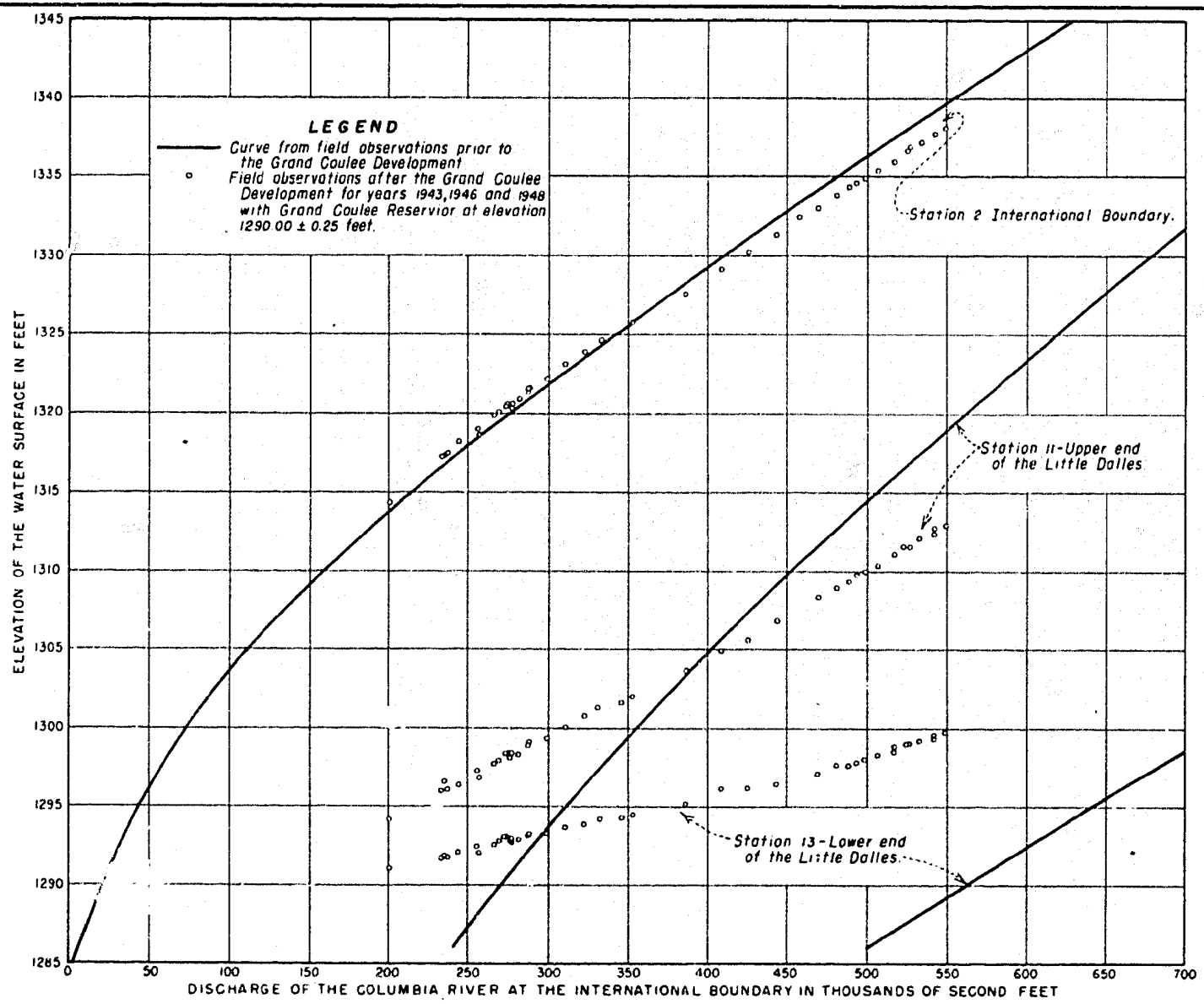

COLUMBIA RIVER BACKWATER STUDIES

WATER SURFACE ELEVATIONS

COMPARISON BEFORE AND AFTER GRAND COULEE DEVELOPMENT

FIGURE 5

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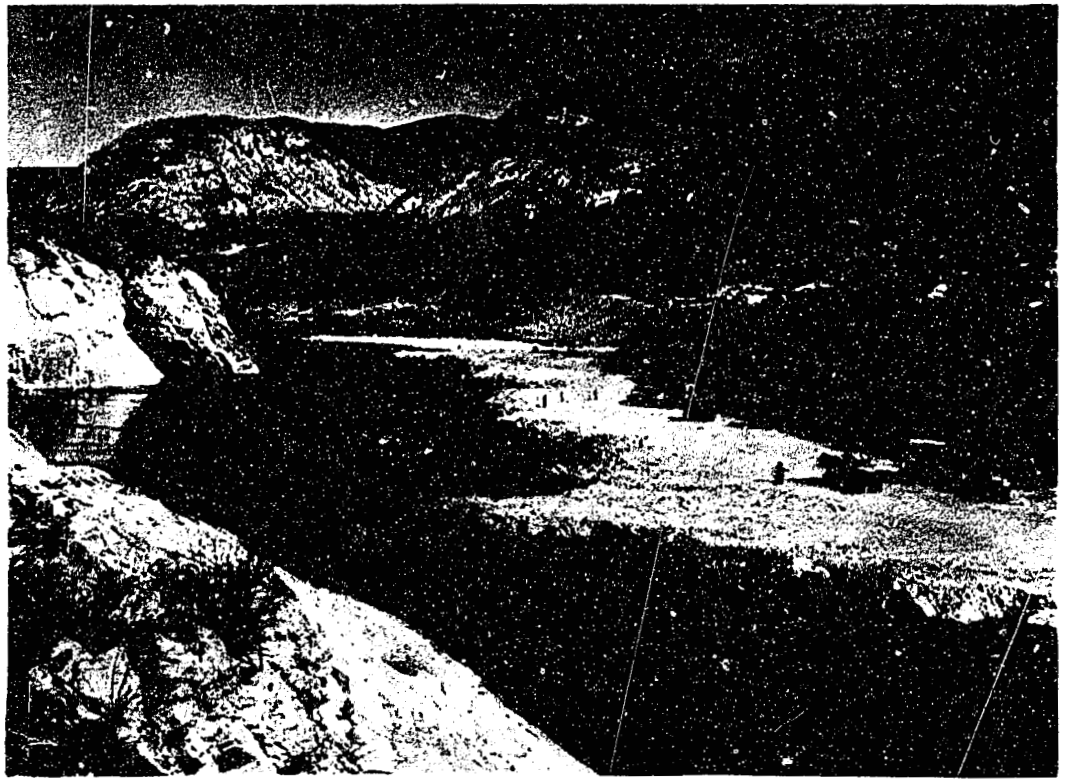
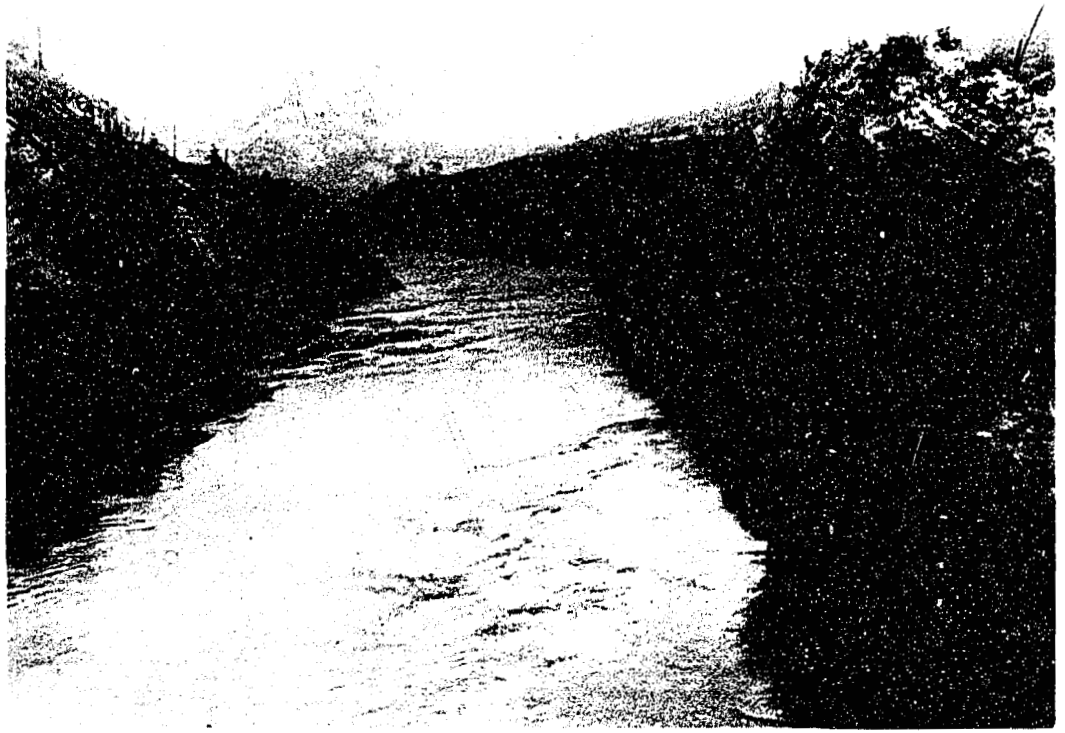
This general view of the Little Dalles shows the hydraulic flow conditions prior to the construction of Grand Coulee Dam and prior to the excavation work through the Little Dalles. The discharge at the time the photograph was made was 330, 600 second-feet.

FIGURE 6



This general view of the Little Dalles was taken on March 26, 1941 when the excavation work was practically completed. The river discharge at this time was 40,000 second-feet. Figure 8 shows a similar view of the Little Dalles taken prior to the excavation work. (H-861-1)

FIGURE 7



This view of the Little Dalles, looking upstream, was taken prior to the excavation work when the river was discharging 50,000 second-feet. Figure 7 shows a similar view taken when the excavation work was practically completed.

FIGURE 8

The 1 to 120 scale hydraulic model of the Little Dalles, looking downstream, is shown in this figure. The excavation plan shown in the model is the same as actually carried out in the field. Figure 10 shows another view of this same model. (61AO)

The 1 to 120 scale hydraulic model of the Little Dalles, looking upstream, is shown in this photograph. The excavation plan shown in the model is the same as actually carried out in the field. Figure 9 shows another view of this same model. (61BO)

The entrance conditions at the Little Dalles prior to any excavation work for a discharge of 330, 600 second-foot are shown in this photograph. Figure 12 shows a similar view of the Little Dalles taken after the excavation work was performed.

FIGURE 11

This photograph of the Little Dalles, looking upstream, was taken on June 10, 1941 after the excavation work was completed. The river flow was 170,000 second-feet. Figure 11 showing another view from a similar vantage point discloses the conditions prior to the excavation work. (H-861-4)

FIGURE 12

The entrance conditions at the Little Dalles prior to any excavation work is shown in this figure. The river flow at the time was 30,000 second-feet. A similar view, taken after the excavation was completed, is shown in figure 14. (H-861-3)

FIGURE 13

This photograph of the entrance to the Little Dalles (looking downstream) was taken on April 1, 1941 at the completion of the excavation work when the river flow was 40, 000 second-feet. Figure 13 shows a similar view of the Little Dalles taken prior to the excavation work. (H-861-2)

FIGURE 14